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OPTICAL DEPTHS IN THE INTERSTELLAR AND INTERGALACTIC MEDIA

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## OPTICAL DEPTHS IN THE INTERSTELLAR AND INTERGALACTIC MEDIA

The purpose of this report is to present optical depths for X rays of the interstellar and intergalactic media in tabular form for varying distances. The optical depth is defined as

$$I = I_0 e^{-\tau}$$

$$\tau = \mu d$$

where  $\mu$  denotes the attenuation coefficient for X rays of the medium, and  $d$  denotes the distance. The term  $\tau$  is dimensionless;  $\mu$  has the dimension ( $\text{cm}^{-1}$ ),  $d$  (cm). The values of  $\mu$  are those for the third cosmic mixture in Reference 1. The distances are those of the identified X-ray sources from the sun.

The results are presented in four tables. Table 1 contains the optical depths for the supernova remnants, Table 2 those for the stars which have been identified as X-ray sources, and Table 3 those for X-ray galaxies. Table 4 contains identifications which have been observed by Uhuru [2].

A density of  $1 \text{ H atom cm}^{-3}$  was assumed for the interstellar medium, and a density of  $2 \times 10^{-5} \text{ H atom cm}^{-3}$  was assumed for the intergalactic medium. These values were taken from Spitzer [3].

The following are given in the tables: the name (or names if several are in use) of the X-ray source, the right ascension and declination of the optical object, the distance of the object from the sun in parsecs ( $1 \text{ pc} = 3.0856 \times 10^{18} \text{ cm}$ ), and, if available, the altitude of the object over the galactic plane in parsecs.

Table 5 contains identifications which have been proposed but which could not be used for computations, since the distances are not yet known [4, 5, 6, 7].

TABLE 1. OPTICAL DEPTHS IN THE GALACTIC PLASMA OF X-RAY SUPERNOVAE SOURCES

	Vela X Vela X-2 h m 8 <sup>h</sup> 32 <sup>m</sup> - 45° 00'	Cygnus Loop Cygnus X-5 h m 20 <sup>h</sup> 49 <sup>m</sup> 30° 30'	Pup A Pup X-1 h m s 8 <sup>h</sup> 20 <sup>m</sup> 30 <sup>s</sup> - 45° 50'	Crab Nebula SN 1054 Tau X-1 h m s 5 <sup>h</sup> 31 <sup>m</sup> 31 <sup>s</sup> 21° 59.0'	Cas A Cas X-1 h m s 23 <sup>h</sup> 21 <sup>m</sup> 11 <sup>s</sup> 58° 32' 48"	Tycho's Nova SN 1572 Cep X-1 h m s 0 <sup>h</sup> 22 <sup>m</sup> 28 <sup>s</sup> 63° 51' 54"
d(pc) z(pc)	500 - 17	770 - 91	1200 - 15	2020 - 373	2700 - 100	5000 121
keV	$\mu$ d	$\mu$ d	$\mu$ d	$\mu$ d	$\mu$ d	$\mu$ d
1500	$3.5484 \cdot 10^{-4}$	$5.4646 \cdot 10^{-4}$	$8.5162 \cdot 10^{-4}$	$1.4336 \cdot 10^{-3}$	$1.9162 \cdot 10^{-3}$	$3.5484 \cdot 10^{-3}$
1000	$4.3507 \cdot 10^{-4}$	$6.7000 \cdot 10^{-4}$	$1.0442 \cdot 10^{-3}$	$1.7577 \cdot 10^{-3}$	$2.3494 \cdot 10^{-3}$	$4.3507 \cdot 10^{-3}$
800	$4.8598 \cdot 10^{-4}$	$7.4841 \cdot 10^{-4}$	$1.1664 \cdot 10^{-3}$	$1.9634 \cdot 10^{-3}$	$2.6243 \cdot 10^{-3}$	$4.8598 \cdot 10^{-3}$
600	$5.5340 \cdot 10^{-4}$	$8.5224 \cdot 10^{-4}$	$1.3282 \cdot 10^{-3}$	$2.2357 \cdot 10^{-3}$	$2.9884 \cdot 10^{-3}$	$5.5340 \cdot 10^{-3}$
500	$5.9814 \cdot 10^{-4}$	$9.2114 \cdot 10^{-4}$	$1.4355 \cdot 10^{-3}$	$2.4165 \cdot 10^{-3}$	$3.2300 \cdot 10^{-3}$	$5.9814 \cdot 10^{-3}$
400	$6.5523 \cdot 10^{-4}$	$1.0090 \cdot 10^{-3}$	$1.5725 \cdot 10^{-3}$	$2.6471 \cdot 10^{-3}$	$3.5382 \cdot 10^{-3}$	$6.5523 \cdot 10^{-3}$
300	$7.3129 \cdot 10^{-4}$	$1.1262 \cdot 10^{-3}$	$1.7551 \cdot 10^{-3}$	$2.9544 \cdot 10^{-3}$	$3.9489 \cdot 10^{-3}$	$7.3129 \cdot 10^{-3}$
200	$8.4129 \cdot 10^{-4}$	$1.2956 \cdot 10^{-3}$	$2.0191 \cdot 10^{-3}$	$3.3988 \cdot 10^{-3}$	$4.5429 \cdot 10^{-3}$	$8.4129 \cdot 10^{-3}$
150	$9.1951 \cdot 10^{-4}$	$1.4160 \cdot 10^{-3}$	$2.2068 \cdot 10^{-3}$	$3.7148 \cdot 10^{-3}$	$4.9653 \cdot 10^{-3}$	$9.1951 \cdot 10^{-3}$
100	$1.0209 \cdot 10^{-3}$	$1.5721 \cdot 10^{-3}$	$2.4501 \cdot 10^{-3}$	$4.1243 \cdot 10^{-3}$	$5.5127 \cdot 10^{-3}$	$1.0209 \cdot 10^{-2}$
80	$1.0635 \cdot 10^{-3}$	$1.6377 \cdot 10^{-3}$	$2.5523 \cdot 10^{-3}$	$4.2963 \cdot 10^{-3}$	$5.7426 \cdot 10^{-3}$	$1.0635 \cdot 10^{-2}$
60	$1.1341 \cdot 10^{-3}$	$1.7465 \cdot 10^{-3}$	$2.7219 \cdot 10^{-3}$	$4.5818 \cdot 10^{-3}$	$6.1242 \cdot 10^{-3}$	$1.1341 \cdot 10^{-2}$
50	$1.1702 \cdot 10^{-3}$	$1.8021 \cdot 10^{-3}$	$2.8085 \cdot 10^{-3}$	$4.7277 \cdot 10^{-3}$	$6.3191 \cdot 10^{-3}$	$1.1702 \cdot 10^{-2}$
40	$1.2129 \cdot 10^{-3}$	$1.8679 \cdot 10^{-3}$	$2.9111 \cdot 10^{-3}$	$4.9003 \cdot 10^{-3}$	$6.5499 \cdot 10^{-3}$	$1.2129 \cdot 10^{-2}$
30	$1.2707 \cdot 10^{-3}$	$1.9568 \cdot 10^{-3}$	$3.0495 \cdot 10^{-3}$	$5.1334 \cdot 10^{-3}$	$6.8615 \cdot 10^{-3}$	$1.2707 \cdot 10^{-2}$
20	$1.3894 \cdot 10^{-3}$	$2.1397 \cdot 10^{-3}$	$3.3347 \cdot 10^{-3}$	$5.6133 \cdot 10^{-3}$	$7.5030 \cdot 10^{-3}$	$1.3894 \cdot 10^{-2}$
15	$1.5605 \cdot 10^{-3}$	$2.4032 \cdot 10^{-3}$	$3.7453 \cdot 10^{-3}$	$6.3046 \cdot 10^{-3}$	$8.4269 \cdot 10^{-3}$	$1.5605 \cdot 10^{-2}$
10	$2.1979 \cdot 10^{-3}$	$3.3847 \cdot 10^{-3}$	$5.2749 \cdot 10^{-3}$	$8.8794 \cdot 10^{-3}$	$1.1868 \cdot 10^{-2}$	$2.1979 \cdot 10^{-2}$
8	$3.0404 \cdot 10^{-3}$	$4.6822 \cdot 10^{-3}$	$7.2969 \cdot 10^{-3}$	$1.2283 \cdot 10^{-2}$	$1.6418 \cdot 10^{-2}$	$3.0404 \cdot 10^{-2}$
6	$5.3733 \cdot 10^{-3}$	$8.2748 \cdot 10^{-3}$	$1.2896 \cdot 10^{-2}$	$2.1708 \cdot 10^{-2}$	$2.9016 \cdot 10^{-2}$	$5.3733 \cdot 10^{-2}$
5	$8.2620 \cdot 10^{-3}$	$1.2723 \cdot 10^{-2}$	$1.9829 \cdot 10^{-2}$	$3.3378 \cdot 10^{-2}$	$4.4615 \cdot 10^{-2}$	$8.2620 \cdot 10^{-2}$
4	$1.4670 \cdot 10^{-2}$	$2.2592 \cdot 10^{-2}$	$3.5208 \cdot 10^{-2}$	$5.9267 \cdot 10^{-2}$	$7.9218 \cdot 10^{-2}$	$1.4670 \cdot 10^{-1}$
3	$3.0825 \cdot 10^{-2}$	$4.7470 \cdot 10^{-2}$	$7.3980 \cdot 10^{-2}$	$1.2453 \cdot 10^{-1}$	$1.6646 \cdot 10^{-1}$	$3.0825 \cdot 10^{-1}$
2	$8.8387 \cdot 10^{-2}$	$1.3612 \cdot 10^{-1}$	$2.1213 \cdot 10^{-1}$	$3.5708 \cdot 10^{-1}$	$4.7729 \cdot 10^{-1}$	$8.8387 \cdot 10^{-1}$
1.5	$1.8483 \cdot 10^{-1}$	$2.8463 \cdot 10^{-1}$	$4.4358 \cdot 10^{-1}$	$7.4670 \cdot 10^{-1}$	$9.9807 \cdot 10^{-1}$	$1.8483$
1	$5.4553 \cdot 10^{-1}$	$8.4012 \cdot 10^{-1}$	$1.3093$	$2.2040$	$2.9459$	$5.4553$

TABLE 2. OPTICAL DEPTHS IN THE GALACTIC PLASMA OF STELLAR X-RAY SOURCES

$\alpha$ $\delta$ d(pc)	$\lambda$	Sco X-1 h <sup>h</sup> 17 <sup>m</sup> 4. 428 - 15° 31' 14." 91 500	Cen X-2 h <sup>h</sup> 9 <sup>m</sup> 38 <sup>s</sup> - 63° 8' 500	Cyg X-1 h <sup>h</sup> 56 <sup>m</sup> 28. 81 35° 3' 54." 1 2000	Cyg X-2 h <sup>h</sup> 42 <sup>m</sup> 36. 91 38° 5' 27." 9 600
keV	Å	$\mu d$			$\mu d$
1500	0.008	3.5484·10 <sup>-4</sup>		1.4194·10 <sup>-3</sup>	4.2581·10 <sup>-4</sup>
1000	0.012	4.3507·10 <sup>-4</sup>		1.7403·10 <sup>-3</sup>	5.2208·10 <sup>-4</sup>
800	0.016	4.8598·10 <sup>-4</sup>		1.9439·10 <sup>-3</sup>	5.8318·10 <sup>-4</sup>
600	0.021	5.5340·10 <sup>-4</sup>		2.2136·10 <sup>-3</sup>	6.6408·10 <sup>-4</sup>
500	0.025	5.9814·10 <sup>-4</sup>		2.3926·10 <sup>-3</sup>	7.1777·10 <sup>-4</sup>
400	0.031	6.5523·10 <sup>-4</sup>		2.6209·10 <sup>-3</sup>	7.8627·10 <sup>-4</sup>
300	0.041	7.3129·10 <sup>-4</sup>		2.9251·10 <sup>-3</sup>	8.7754·10 <sup>-4</sup>
200	0.062	8.4129·10 <sup>-4</sup>		3.3652·10 <sup>-3</sup>	1.0095·10 <sup>-3</sup>
150	0.083	9.1951·10 <sup>-4</sup>		3.6780·10 <sup>-3</sup>	1.1034·10 <sup>-3</sup>
100	0.124	1.0209·10 <sup>-3</sup>		4.0835·10 <sup>-3</sup>	1.2250·10 <sup>-3</sup>
80	0.155	1.0635·10 <sup>-3</sup>		4.2538·10 <sup>-3</sup>	1.2761·10 <sup>-3</sup>
60	0.207	1.1341·10 <sup>-3</sup>		4.5364·10 <sup>-3</sup>	1.3609·10 <sup>-3</sup>
50	0.248	1.1702·10 <sup>-3</sup>		4.6809·10 <sup>-3</sup>	1.4043·10 <sup>-3</sup>
40	0.310	1.2129·10 <sup>-3</sup>		4.8518·10 <sup>-3</sup>	1.4555·10 <sup>-3</sup>
30	0.413	1.2707·10 <sup>-3</sup>		5.0826·10 <sup>-3</sup>	1.5248·10 <sup>-3</sup>
20	0.620	1.3894·10 <sup>-3</sup>		5.5578·10 <sup>-3</sup>	1.6673·10 <sup>-3</sup>
15	0.827	1.5605·10 <sup>-3</sup>		6.2422·10 <sup>-3</sup>	1.8727·10 <sup>-3</sup>
10	1.240	2.1979·10 <sup>-3</sup>		8.7915·10 <sup>-3</sup>	2.6374·10 <sup>-3</sup>
8	1.550	3.0404·10 <sup>-3</sup>		1.2162·10 <sup>-2</sup>	3.6485·10 <sup>-3</sup>
6	2.066	5.3733·10 <sup>-3</sup>		2.1493·10 <sup>-2</sup>	6.4479·10 <sup>-3</sup>
5	2.480	8.2620·10 <sup>-3</sup>		3.3048·10 <sup>-2</sup>	9.9144·10 <sup>-3</sup>
4	3.099	1.4670·10 <sup>-2</sup>		5.8680·10 <sup>-2</sup>	1.7604·10 <sup>-2</sup>
3	4.133	3.0825·10 <sup>-2</sup>		1.2330·10 <sup>-1</sup>	3.6990·10 <sup>-2</sup>
2	6.199	8.8387·10 <sup>-2</sup>		3.5355·10 <sup>-1</sup>	1.0606·10 <sup>-1</sup>
1.5	8.265	1.8483·10 <sup>-1</sup>		7.3931·10 <sup>-1</sup>	2.2179·10 <sup>-1</sup>
1	12.398	5.4553·10 <sup>-1</sup>		2.1821	6.5464·10 <sup>-1</sup>

TABLE 3. OPTICAL DEPTHS IN THE INTERGALACTIC PLASMA OF GALACTIC SOURCES

	LMC X-1	LMC X-2	LMC X-3	SMC X-1	NGC 5128	M 87 Vir A	3C 273
$\alpha$ $\delta$ d(pc)	$5^{\text{h}} 40^{\text{m}} 33^{\text{s}}.6$ $-69^{\circ} 36'$ $5.2 \cdot 10^4$	$5^{\text{h}} 19^{\text{m}} 2.4$ $-72^{\circ} 33' 36''$ $5.2 \cdot 10^4$	$5^{\text{h}} 38^{\text{m}} 43^{\text{s}}.2$ $-64^{\circ} 6' 36''$ $5.2 \cdot 10^4$	$1^{\text{h}} 14^{\text{m}} 48^{\text{s}}$ $-73^{\circ} 42'$ $5.4 \cdot 10^4$	$13^{\text{h}} 22^{\text{m}} 30^{\text{s}}$ $-42^{\circ} 46' 12''$ $4 \cdot 10^6$	$12^{\text{h}} 28^{\text{m}} 18^{\text{s}}$ $12^{\circ} 40'$ $1.25 \cdot 10^7$	$12^{\text{h}} 26^{\text{m}} 30^{\text{s}}$ $2^{\circ} 19'$ $6.30 \cdot 10^8$
keV	$\mu\text{d}$				$\mu\text{d}$		$\mu\text{d}$
1500	$7.3807 \cdot 10^{-7}$				$5.6773 \cdot 10^{-5}$		$8.9419 \cdot 10^{-3}$
1000	$9.0494 \cdot 10^{-7}$				$6.9609 \cdot 10^{-5}$		$1.0964 \cdot 10^{-2}$
800	$1.0108 \cdot 10^{-6}$				$7.7755 \cdot 10^{-5}$		$1.2247 \cdot 10^{-2}$
600	$1.1511 \cdot 10^{-6}$				$8.8542 \cdot 10^{-5}$		$1.3946 \cdot 10^{-2}$
500	$1.2441 \cdot 10^{-6}$				$9.5700 \cdot 10^{-5}$		$1.5073 \cdot 10^{-2}$
400	$1.3629 \cdot 10^{-6}$				$1.0483 \cdot 10^{-4}$		$1.6511 \cdot 10^{-2}$
300	$1.5211 \cdot 10^{-6}$				$1.1700 \cdot 10^{-4}$		$1.8428 \cdot 10^{-2}$
200	$1.7499 \cdot 10^{-6}$				$1.3460 \cdot 10^{-4}$		$2.1200 \cdot 10^{-2}$
150	$1.9151 \cdot 10^{-6}$				$1.4712 \cdot 10^{-4}$		$2.3171 \cdot 10^{-2}$
100	$2.1234 \cdot 10^{-6}$				$1.6333 \cdot 10^{-4}$		$2.5726 \cdot 10^{-2}$
80	$2.2120 \cdot 10^{-6}$				$1.7015 \cdot 10^{-4}$		$2.6799 \cdot 10^{-2}$
60	$2.3589 \cdot 10^{-6}$				$1.8145 \cdot 10^{-4}$		$2.8579 \cdot 10^{-2}$
50	$2.4340 \cdot 10^{-6}$				$1.8723 \cdot 10^{-4}$		$2.9489 \cdot 10^{-2}$
40	$2.5229 \cdot 10^{-6}$				$1.9407 \cdot 10^{-4}$		$3.0566 \cdot 10^{-2}$
30	$2.6429 \cdot 10^{-6}$				$2.0330 \cdot 10^{-4}$		$3.2020 \cdot 10^{-2}$
20	$2.8900 \cdot 10^{-6}$				$2.2230 \cdot 10^{-4}$		$3.5014 \cdot 10^{-2}$
15	$3.2459 \cdot 10^{-6}$				$2.4968 \cdot 10^{-4}$		$3.9325 \cdot 10^{-2}$
10	$4.5715 \cdot 10^{-6}$				$3.5165 \cdot 10^{-4}$		$5.5386 \cdot 10^{-2}$
8	$6.3240 \cdot 10^{-6}$				$4.8645 \cdot 10^{-4}$		$7.6617 \cdot 10^{-2}$
6	$1.1176 \cdot 10^{-5}$				$8.5969 \cdot 10^{-4}$		$1.3540 \cdot 10^{-1}$
5	$1.7185 \cdot 10^{-5}$				$1.3219 \cdot 10^{-3}$		$2.0820 \cdot 10^{-1}$
4	$3.0513 \cdot 10^{-5}$				$2.3471 \cdot 10^{-3}$		$3.6968 \cdot 10^{-1}$
3	$6.4116 \cdot 10^{-5}$				$4.9319 \cdot 10^{-3}$		$7.7678 \cdot 10^{-1}$
2	$1.8384 \cdot 10^{-4}$				$1.4141 \cdot 10^{-2}$		2.2273
1.5	$3.8444 \cdot 10^{-4}$				$2.9571 \cdot 10^{-2}$		4.6576
1	$1.1347 \cdot 10^{-3}$				$8.7283 \cdot 10^{-2}$		$1.3747 \cdot 10^{-1}$

TABLE 4. X-RAY GALAXIES OBSERVED BY UHURU

	NGC 5128	NGC 4151	NGC 1275 Perseus	NGC 4874
$\alpha$	$13^{\text{h}} 22^{\text{m}} 29^{\text{s}}$	$12^{\text{h}} 8^{\text{m}} 1^{\text{s}}$	$3^{\text{h}} 16^{\text{m}} 50^{\text{s}}$	$12^{\text{h}} 57^{\text{m}} 14^{\text{s}}$
$\delta$	$-42^{\circ} 45' 30''$	$39^{\circ} 41'$	$41^{\circ} 19' 42''$	$28^{\circ} 15' 42''$
d(pc)	$5 \cdot 10^8$	$1.3 \cdot 10^7$	$7 \cdot 10^7$	$9 \cdot 10^7$
keV	$\mu\text{d}$	$\mu\text{d}$	$\mu\text{d}$	$\mu\text{d}$
1500	$7.0969 \cdot 10^{-5}$	$1.8452 \cdot 10^{-4}$	$9.9356 \cdot 10^{-4}$	$1.2774 \cdot 10^{-3}$
1000	$8.7014 \cdot 10^{-5}$	$2.2624 \cdot 10^{-4}$	$1.2182 \cdot 10^{-3}$	$1.5663 \cdot 10^{-3}$
800	$9.7196 \cdot 10^{-5}$	$2.5271 \cdot 10^{-4}$	$1.3607 \cdot 10^{-3}$	$1.7495 \cdot 10^{-3}$
600	$1.1068 \cdot 10^{-4}$	$2.8777 \cdot 10^{-4}$	$1.5495 \cdot 10^{-3}$	$1.9922 \cdot 10^{-3}$
500	$1.1963 \cdot 10^{-4}$	$3.1103 \cdot 10^{-4}$	$1.6748 \cdot 10^{-3}$	$2.1533 \cdot 10^{-3}$
400	$1.3105 \cdot 10^{-4}$	$3.4072 \cdot 10^{-4}$	$1.8346 \cdot 10^{-3}$	$2.3588 \cdot 10^{-3}$
300	$1.4626 \cdot 10^{-4}$	$3.8027 \cdot 10^{-4}$	$2.0476 \cdot 10^{-3}$	$2.6326 \cdot 10^{-3}$
200	$1.6770 \cdot 10^{-4}$	$4.3747 \cdot 10^{-4}$	$2.3556 \cdot 10^{-3}$	$3.0286 \cdot 10^{-3}$
150	$1.8390 \cdot 10^{-4}$	$4.7814 \cdot 10^{-4}$	$2.5746 \cdot 10^{-3}$	$3.3102 \cdot 10^{-3}$
100	$2.0417 \cdot 10^{-4}$	$5.3085 \cdot 10^{-4}$	$2.8584 \cdot 10^{-3}$	$3.6751 \cdot 10^{-3}$
80	$2.1269 \cdot 10^{-4}$	$5.5300 \cdot 10^{-4}$	$2.9777 \cdot 10^{-3}$	$3.8284 \cdot 10^{-3}$
60	$2.2682 \cdot 10^{-4}$	$5.8974 \cdot 10^{-4}$	$3.1755 \cdot 10^{-3}$	$4.0828 \cdot 10^{-3}$
50	$2.3404 \cdot 10^{-4}$	$6.0851 \cdot 10^{-4}$	$3.2766 \cdot 10^{-3}$	$4.2128 \cdot 10^{-3}$
40	$2.4259 \cdot 10^{-4}$	$6.3073 \cdot 10^{-4}$	$3.3963 \cdot 10^{-3}$	$4.3666 \cdot 10^{-3}$
30	$2.5413 \cdot 10^{-4}$	$6.6074 \cdot 10^{-4}$	$3.5578 \cdot 10^{-3}$	$4.5743 \cdot 10^{-3}$
20	$2.7789 \cdot 10^{-4}$	$7.2251 \cdot 10^{-4}$	$3.8904 \cdot 10^{-3}$	$5.0020 \cdot 10^{-3}$
15	$3.1211 \cdot 10^{-4}$	$8.1148 \cdot 10^{-4}$	$4.3695 \cdot 10^{-3}$	$5.6180 \cdot 10^{-3}$
10	$4.3957 \cdot 10^{-4}$	$1.1429 \cdot 10^{-3}$	$6.1540 \cdot 10^{-3}$	$7.9123 \cdot 10^{-3}$
8	$6.0808 \cdot 10^{-4}$	$1.5810 \cdot 10^{-3}$	$8.5131 \cdot 10^{-3}$	$1.0945 \cdot 10^{-2}$
6	$1.0747 \cdot 10^{-3}$	$2.7941 \cdot 10^{-3}$	$1.5045 \cdot 10^{-2}$	$1.9344 \cdot 10^{-2}$
5	$1.6524 \cdot 10^{-3}$	$4.2962 \cdot 10^{-3}$	$2.3134 \cdot 10^{-2}$	$2.9743 \cdot 10^{-2}$
4	$2.9340 \cdot 10^{-3}$	$7.6284 \cdot 10^{-3}$	$4.1076 \cdot 10^{-2}$	$5.2812 \cdot 10^{-2}$
3	$6.1650 \cdot 10^{-3}$	$1.6029 \cdot 10^{-2}$	$8.6310 \cdot 10^{-2}$	$1.1097 \cdot 10^{-1}$
2	$1.7677 \cdot 10^{-2}$	$4.5961 \cdot 10^{-2}$	$2.4748 \cdot 10^{-1}$	$3.1819 \cdot 10^{-1}$
1.5	$3.6965 \cdot 10^{-2}$	$9.6110 \cdot 10^{-2}$	$5.1752 \cdot 10^{-1}$	$6.6538 \cdot 10^{-1}$
1	$1.0911 \cdot 10^{-1}$	$2.8368 \cdot 10^{-1}$	$1.5275$	$1.9639$

TABLE 5. PROPOSED IDENTIFICATIONS OF X-RAY STARS

Name	$\alpha$	$\delta$
Cyg X-1	$19^{\text{h}} 56^{\text{m}} 28.81^{\text{s}}$	$35^{\circ} 03' 54.1''$
Cen X-3	$11^{\text{h}} 18^{\text{m}} 56.4^{\text{s}}$	$60^{\circ} 15' 48''$
G X 3 + 1	$17^{\text{h}} 42^{\text{m}} 42^{\text{s}}$	$- 26^{\circ} 10'$
2 ASA 0352 + 30	$3^{\text{h}} 52^{\text{m}} 15^{\text{s}}$	$30^{\circ} 54'$



## REFERENCES

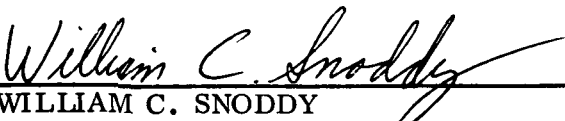
1. Schocken, K.: The Attenuation of X-Rays in Interstellar Space. J. Appl. Phys., (to be published Aug. 1972).
2. Cavaliere, A. G.; Gursky, H.; and Tucker, W. H.: Extragalactic X-Ray Sources and Associations of Galaxies. Nature, no. 231, 1971, pp. 437-438.
3. Spitzer, L.: Diffuse Matter in Space. Interscience Publishers, New York-London-Sidney-Toronto, 1968.
4. Braes, L. L. E. and Miley, G. K.: Further Radio Observations of Cygnus X-1. Nature Phys. Sci., no. 235, 1972, p. 147.
5. Margon, B. and Wray, J. D.: On the Optical Identification of Centaurus X-3. Astrophys. J., no. 174, 1972, pp. L141 - L142.
6. Blanco, V.; Kunkel, W.; Hiltner, W. A.; Lynga, G.; Bradt, H.; Clark, C.; Naranan, S.; Rappaport, S.; and Spada, G.: An Optical Search for X-Ray Sources in Sagittarius. Astrophys. J., no. 152, 1968, pp. 1015 - 1017.
7. van den Bergh, S.: Possible Identification of X Persei with an X-Ray Source. Nature, no. 235. 1972, pp. 273 - 274.

## OPTICAL DEPTHS IN THE INTERSTELLAR AND INTERGALACTIC MEDIA

By Klaus Schocken

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This document has also been reviewed and approved for technical accuracy.

  
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